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A COMPARISON OF SOME APPROACHES TO THE CLASSIFICATION OF ROCK MASSES FOR GEOTECHNICAL PURPOSES

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October 1984

This document is an interim report prepared for ... and represents the ... (CANMET)

... rapport intérimaire préparé ... et représente la ... (MRT)

21 pp

MINERALS RESEARCH PROGRAM
MINING RESEARCH LABORATORIES
DIVISION REPORT MRP/MRL 84-97(TR)

FEB 27 1985
MICROMEDIA

A COMPARISON OF SOME APPROACHES TO THE CLASSIFICATION OF ROCK MASSES FOR GEOTECHNICAL PURPOSES

by

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ABSTRACT

Rock mass classif[illegible]ion systems, incorporating both strength and structural properties, permit an engineer to compare the conditions encountered at a local site with those that have been described elsewhere. Such comparisons add precision to the design of underground openings and support systems.

In this study, conducted at a mine in the Province of Quebec, the authors used four different approaches to classification systems in order to obtain numerical values which are possible indicators of the qualities of local conditions in the rock mass.

Both the on-site experience and comparisons between the results have led to a number of conclusions regarding the strengths and weaknesses of the systems used.

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COMPARAISON DE CERTAINES MÉTHODES DE CLASSIFICATION DES MASSES ROCHEUSES À DES FINS GÉOTECHNIQUES

par

John E. Udd* et Haifeng Wang**

RÉSUMÉ

Les systèmes de classification des masses rocheuses comprenant la classification des propriétés de résistance et des caractéristiques structurales permettent aux ingénieurs de comparer les conditions à l'emplacement d'un projet aux conditions qui existent à d'autres emplacements et dont on possède la description. De telles comparaisons permettent de concevoir avec plus de précision les ouvertures et les systèmes de soutènement.

Les auteurs de la présente étude effectuée dans une mine de la province de Québec ont utilisé quatre méthodes différentes pour établir des systèmes de classification afin d'obtenir des valeurs numériques qui pourraient devenir des indicateurs possibles des qualités de la géométrie interne de la masse rocheuse.

Les expériences faites sur les lieux et la comparaison des résultats ont permis d'arriver à certaines conclusions quant aux mérites et aux faiblesses des systèmes utilisés.

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** Monsieur Wang, ingénieur en exploitation minière du Hunan Uranium Mining Research Laboratories Institute de la République populaire de Chine, participait à un programme d'échange au moment où cette étude a été effectuée. Depuis, M. Wang est retourné dans son pays.

INTRODUCTION

In designing an excavation in rock, and the supporting system(s) that may be required, an engineer must make a number of decisions based on assessments of the local strength and structural conditions.

Any excavation will interfere with the pre-existing state of equilibrium. The challenge to the geotechnical engineer is to ensure that a new state of equilibrium is attained and maintained.

The properties of both the geological materials and any contained discontinuities, or zones of weakness, influence the process of design very considerably. Some of the key parameters for underground mining, such as maximum permissible spans, extraction ratios, and the dimensions of the pillars between openings, must be related to the self-supporting capabilities of the local rock mass. Additional support is used, whenever necessary, to alter these parameters to more acceptable values.

Many of the decisions that are made during design must derive from an appreciation of the conditions that are anticipated in the rock mass. During the process it is very valuable if one is able to consider the experiences that have been gained by others in designing excavations in similar materials. Comparisons become meaningful, however, only when a well-defined and standardized method of reporting has been used.

To that end, there has been considerable activity around the world in the development of rock mass classification systems. An acceptable and universally-adopted system would, in the ideal case, permit reasonably accurate and understandable comparisons to be made between the conditions encountered at various sites. Differences due to factors other than local conditions should be at an absolute minimum. Unfortunately, our understanding of the importances of the different properties of rocks and of rock masses has not progressed to the point at which there is unanimous agreement that one particular classification system should be used.

Historically, the evolution of classification systems closely follows the trends in thinking that have taken place in rock mechanics. To illustrate this, one of the early attempts to predict the in situ strength of a rock mass, by Protodyakonov (1), was based on a strength property which could be determined in a laboratory. Others, notably Terzaghi's (2), were based on observations that had been made in the field. It is interesting to note that one may find some instances in present practice in which the early methods mentioned have been used.

With time and experience it was realized that the compressive strength of a rock mass is strongly influenced, if not governed, by the properties of contained discontinuities. Both the systems proposed by Coates (3) and Deere (4) are examples of this next stage. Coates' system was based on the compressive strength and deformational properties of samples of intact rock, and on the extent to which a rock mass is fractured. Deere's "Rock Quality Designation" (RQD) is determined from assessments of the extent of fracturing in diamond drill core. While Coates' proposed method is now obsolete, Deere's approach, and many variations which are similar to it, are in common use today.

At the present stage of the development of classification systems it is recognized that many factors should be considered when estimating the properties of a rock mass. The strength of the rock in the laboratory, however, is considered to be much less important that it was previously. Simultaneously, the properties of the discontinuities in a rock mass are assigned preeminent importance. In both the South African (CSIR) (5) and Norwegian (NGI) (6) methods, which are in widespread use today, the degree of fracturing and the conditions of the fractures, are assigned at least three quarters of the points by which ratings are obtained. The diminution in the importance given to the compressive strength of samples of intact rock is illustrated by the fact that this variable is not even included in the Norwegian approach.

In this study, the authors were afforded an opportunity to assess the advantages and disadvantages of some of the available classification systems. The objective of the work was to select a method which is suitable for regular use under actual operating conditions in an underground mine. It was considered to be of primary importance that the method selected should be suitable for the use of mine personnel (as opposed to specialists).

BACKGROUND

At the mine site, a classification system for the local rocks had been in use for some time. Since the local rocks exhibit progressive degrees of alteration, and since it was assumed that the most highly altered rocks would be the weakest, the classes were selected to correspond with the stages of alteration that could be identified during core-logging operations. A summary of the local system that was in use prior to this study is shown in

Table 1. It must be noted that the relationship between alteration and strength which had been assumed was subsequently proven to be correct. Within the scale of classification, however, it was also shown that some changes should be made to the original ordering of the groups. As might be expected, the strength testing disclosed some anomalies in the assumed order of the results. This will be discussed shortly.

Table 1 - The rock classification system, based on an assumed relationship between alteration and strength, in use before this study

Rock type	Description
A	Meta-anorthosite. Very hard and competent, but brittle. Approximately 70-90% feldspars. Has a tendency to break along fractures, slips, and fault planes.
B	Altered anorthosite with 15-20% feldspar ghosts - most of which are broken to zoisite stage. The balance is massive carbonatized sericite.
C	Massive sericite and chlorite alteration. Poorly sheared with fair degree of carbonation.
D	Massive sericite with high degree of carbonation. Low degree of shearing, with a tendency to slab.
E	Fairly foliated sericite with a fair degree of alteration. Quite slabby.
F	Fairly altered sericite with a fair degree of shearing. Occasional streaks of fuschite and some random grains of chloritoid.
G	Increase in chloritoids with occasional carbonate bands. Peels off along foliation or fault planes.
H	Chloritoids may be completely missing. At places, minor drag folds are visible near zones of heavy shearings.
I	High degree of alteration and highly sheared. Sericite along schistosity planes becomes quite talcose.
J	Very high degree of alteration. Quite talcose. Sericite is intensely sheared, twisted, or crumpled. Flaky - at times individual lamella can be peeled off.

As mentioned, one of the particular objectives of this study was to compare the newer methods of rock mass classification with that being used by the company prior to this study. The intent was not only to determine if improvements could be made to the existing system but also to select that method which could best be used subsequently for geotechnical purposes; such as, for estimating the requirements for support in different areas of the mine.

THE CLASSIFICATION SYSTEMS CONSIDERED

For reasons which will be elaborated below, four different approaches were considered in this study. These were:

(1) The Russian Method - Rock Consolidation Coefficients
(2) Deere's Method - Rock Quality Designations
(3) The South African Method - CSIR Geomechanics Classification
(4) The Norwegian Method - NGI Tunnelling Quality Index.

1) THE RUSSIAN METHOD

In 1907, M.M. Protodyakonov suggested that the strength of a rock mass could be expressed by a "rock consolidation coefficient". This coefficient is obtained by dividing the strength of samples of intact rock by 100. Thus;

$$f = \frac{\sigma_c}{100}$$

in which:

f = Rock Consolidation Coefficient (RCC)
σ_c = Uniaxial Compressive Strength (originally in kg/cm^2)

The approach, which is based on the assumption that the strengths of rock masses are related only to the strengths of samples of intact rock, through a common factor, is now obsolete. It is, however, similar in concept to the classification system that was in use at the mine prior to the commencement of this study.

For this reason, and because values for the strengths of intact rocks were required for other purposes - in particular, as input information in order to obtain CSIR Classifications - the authors decided to calculate coefficients according to the Russian approach (noting that different units are in use at present). Any relationship between the system in use at the mine and the Russian system must also be similar to a relationship between alteration and strength.

2) DEERE'S METHOD

In 1964, Deere proposed that the quality of the core obtained by diamond drilling could be used as a basis for estimating the quality of a rock mass. His "Rock Quality Designation", or RQD, is based on the percentage of the core in a given run that exceeds a certain minimum length. Thus;

$$\text{RQD } (\%) = 100 \times \frac{\text{Total length of all pieces exceeding 10 cm}}{\text{Total length of core run (m)}}$$

In calculating values for RQD, an investigator must take care to differentiate between naturally-occurring fractures in the rock mass and those which might have been induced by drilling. The latter, which increase in frequency as the size of core is decreased, can result in substantial errors in the results. It is normally accepted that the diameter of the core which is used to obtain RQD values should not be less than about 5 cm. A typical run might be of the order of 2 m.

Because it is both simple and practical, Deere's approach has been widely accepted. There are, at the same time, a number of other methods, such as the establishment of fracture frequencies, that are very similar in concept. The method, however, results in a single parameter. It is generally agreed that much additional information is required if one wishes to obtain rock mass classifications that are useful for purpose of comparison.

In the present investigation both the South African and Norwegian methods were used. Values of RQD are required for both as basic input information. Thus, the use of Deere's approach was absolutely necessary.

In this instance, however, drill core for the locations for which ratings were obtained was not available. As an alternative to direct evaluations the authors used a formula, suggested by Hoek and Brown (7), to estimate approximate values. The formula given is:

$$RQD = 115 - 3.3\ (J_v)$$

in which:

J_v = Total number of joints per cubic metre

Data was produced by estimating the total number of joints at each of the sites visited and calculating approximate values of RQD through the above formula. From a practical point of view, the technique was found to be both efficient and satisfactory.

3) THE CSIR GEOMECHANICS CLASSIFICATION METHOD

Proposed by Bieniawski, of the Council for Scientific and Industrial Research, of South Africa, the CSIR Geomechanics Classification System has become widely accepted. The particular features are that the present version has been developed after extensive validation work in the field and a number of modifications leading to improvements. Additionally, the system incorporates not one, but several parameters. These are:

(1) Intact rock strength (obtained through either uniaxial compression or point load tests)
(2) Rock quality designation
(3) Spacing of joints
(4) Condition of joints
(5) Inflow of groundwater

Another parameter, relating to the importance of the orientations of joints with respect to the particular opening, is used to adjust initial overall ratings.

Recognizing that each of the parameters contributes unequally to the structural behaviour of a rock mass, Bieniawski proposed that each should be

assigned a number of ranges of values together with importance ratings. The procedure in the field, then, is to select the ranges of values which are appropriate for each parameter. The individual ratings obtained are then added, and an adjustment made in respect of joint orientations.

Because of the way in which it has been designed, validated, and accepted, the CSIR method was one of the two principal methods considered by the authors.

4) THE NGI TUNNELLING QUALITY INDEX

The other principal method evaluated was developed at the Norwegian Geotechnical Institute. It is significant that both this and the CSIR method were developed in Shield-type rocks that are similar in many respects to those in Canada. Unlike the South African method, however, the Norwegian approach was based largely on civil engineering experience with tunnels. From a mining point of view, this may have resulted in over-conservatism.

The NGI approach involves six parameters. It is note-worthy that none of these are related directly to the compresssive strength of either intact or in situ rock. Strength is incorporated in an indirect way, however, through two of the parameters.

As in the previous method, ranges of values are suggested for each of the parameters. As a first step in calculating a tunnelling quality index an investigator first selects, from lists for each parameters, the descriptions of quality which match most closely the conditions assessed for the site. Each description of conditions in the lists is accompanied by a numerical value. Having determined these, then, one is able to calculate a tunnelling quality index, Q, from the following formula:

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF}$$

in which:

RQD = Rock Quality Designation
J_n = Joint Set Number
J_r = Joint Roughness Number
J_a = Joint Alteration Number
J_w = Joint Water Reduction Factor
SRF = Stress Reduction Factor

At a first glance the formula and the accompanying tables of descriptions and values appear to be complicated. This is unfortunate, for, in fact, the method is easy to use in the field. Nonetheless, it must be observed that the adoption of the method by mine operators would be facilitated by improvements in appearance. The authors' solution to this, in connection with this project, will be shown shortly.

Because of the features of the NGI approach the authors selected it as one of the two principal methods to be considered in this project.

THE FIELD PROGRAM

During a period at the mine the authors, working together with the geological staff, reviewed the local geology and the rock classification system and selected a total of 153 underground sites for detailed assessments. The locations were chosen with the objective of encompassing all of the defined rock types and the widest possible ranges of structural conditions. Unfortunately, since some of the rock types are encountered less frequently than others it was not possible to select an equal number of sites for each type. Very few exposures were available in the rocks that were assumed to be the strongest. A summary of the sites evaluated is given in Table 2.

Using a simplified two-sided classification form, which was designed to permit rapid on-site evaluations, the conditions at each of the sites were recorded. An example of the form used is shown in Tables 3(a) and 3(b). It should be noted that an effort was made to condense all of the information required in order to achieve a classification value to the extent that a single page could be used for each location. The forms were used without any difficulty and are recommended for the use of others.

Table 2 - Summary of the sites at which classifications were made

Rock type	Number of sites
A	1
B	5
C	10
D	29
E	17
F	19
G	8
H	12
I	18
J	34
Total	153

Table 3(a) - CSIR Classification Form

Mine _____ Level _____ Location _____

Rock type _____

1) Strength - Uniaxial Compression

	>200 MPa	200-100	100-50	50-25	25-10
Rating	15	12	7	4	2

2) RQD

	100-90%	90-75%	75-50%	50-25%	<25%
Rating	20	17	13	8	3

3) Joint spacing

	>3 mm	3-1 m	1-0.3 m	300-50 mm	<50 mm
Rating	30	25	20	10	5

4) Joint condition

	Very rough Not continuous No separation Hard wall rock	Sl. rough Sep. <1 mm Hard rock	Sl. rough Sep. <1 mm Soft rock	Slickenside Gouge <5 mm Open 1-5 mm Continuous	Gouge >5 mm Open >5 mm Continuous
Rating	25	20	12	6	0

5) Water

	Dry	Dry	Moist	Moderate	Severe
Rating	10	10	7	4	0

6) Adjustment for joint orientations

	V. favourable	Favourable	Fair	Unfavourable	V. unfavourable
Rating	0	-2	-5	-10	-12

TOTAL RATING

100 - 81	Very good rock	Class I
80 - 61	Good rock	Class II
60 - 41	Fair rock	Class III
40 - 21	Poor rock	Class IV
<20	Very poor rock	Class V

Table 3(b) - NGI Classification Form

Mine _____ Level _____ Location _____

Rock type _____

1) RQD

a) Very poor:	0 - 25%	___
b) Poor:	25 - 50	___
c) Fair:	50 - 75	___
d) Good:	75 - 90	___
e) Excellent:	90 - 100	___

(Note: If J_v = no. of joints/m^3, approx. RQD = 115 - 3.3 J_v)

2) J_n

a) Massive, no joints	0.5-1.0	___
b) One set	2	___
c) One set + random	3	___
d) Two sets	4	___
e) Two sets + random	6	___
f) Three sets	9	___
g) Three sets + random	12	___
h) Four or more sets	15	___
j) Crushed	20	___

(Note: Intersections ___x3)
Portals ___x2)

3) J_r - weakest, unfavourable set

a) Discontinuous	4	___
b) Rough, undulating	3	___
c) Smooth, undulating	2	___
d) Slickensided, und.	1.5	___
e) Irregular, planar	1.5	___
f) Smooth, planar	1	___
g) Slickensided, planar	0.5	___
h) Clay, no contact	1	___
j) Crushed, no contact	1	___

(Note: If spacing >3 m, add 1)

4) J_a - weakest, unfavourable set

a) Tightly healed, hard	0.75	___
b) Unaltered	1	___
c) Slightly altered	2	
d) Silty, sandy coatings	3	
e) Mineral coatings (incl. chlorite, etc.)	4	___
f) Sandy particles	4	___
g) Strongly consol. clay	6	___
h) Medium consol. clay	8	___
j) Swelling clay	8-12	___
k) Disintegrated	6-8	___

5) J_w

a) Dry	1	___
b) Medium inflow	0.66	___
c) Large inflow	0.5	___
d) Larger inflow	0.33	___
e) Highest inflow	0.2-0.1	___
f) Less with time No decay (time)	0.1-0.05	___

6) SRF

a) Multiple weaknesses, clay	10	___
b) Single weaknesses, clay (<50 m)	5	___
c) Single weaknesses, clay (>50 m)	2.5	___
d) Multiple shears	7.5	___
e) Single shears (<50 m)	5	___
f) Single shears (>50 m)	2.5	___
g) Loose, open	5	___
h) Low stress	2.5	___
j) Medium stress	1	___
k) High stress	0.5- 2	___
l) Mild burst	5-10	___
m) Heavy burst	10-20	___

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF}$$

$$= ____ \times __ \times ____$$

$$=$$

Referring to the forms, it should be observed that not all of the information required to obtain classifications could be determined during the visits to the sites. In particular, values for RQD and the strengths of intact rock samples are necessary.

With respect to the former, however, the authors used the approximation technique suggested by Hoek and Brown to estimate the values while at the locations. As no difficulties were encountered, it can be stated with some confidence that the technique is an acceptable substitute. Care was taken to be as certain as possible that any fractures thought to have been induced by blasting were not included when making the estimates.

The strengths of samples of the rocks were determined through conventional standardized laboratory tests. Groups of twelve samples were selected, from the drill core in storage, for each of the rock types. These were subsequently tested in the laboratory at McGill. A summary of the results obtained is given in Table 4.

Table 4 - Summary of compressive strengths of rock tested

Rock type	Number of samples tested	Uniaxial compressive strength (MPa)	Standard deviation %
A	12	190,86	63,1
B	12	104,91	23,6
C	12	80,78	27,8
D	12	63,58	21,5
E	12	81,90	22,9
F	12	116,78	19,9
G	12	68,11	45,5
H	12	87,17	20,7
I	12	67,35	42,4
J	12	47,98	48,3

Note: All of the samples tested were 3,2 cm in diameter and 8,0 cm long.

Having obtained all of the data required, the authors then calculated rock mass classification values according to both the South African and the Norwegian methods. A summary of these results is given in Table 5.

Table 5 - Summary of classification values obtained for each of the rock types

Rock type	Number of sites	Average CSIR rating	Range of values	Average NGI rating	Range of values
A	1	69	-	150,0	-
B	5	81,8	68-95	232,8	13,3-533,0
C	10	63,5	46-85	66,0	0,42-300,0
D	29	65,3	40-85	65,0	0,6-533,0
E	17	59,9	46-80	15,4	0,33-63,3
F	19	67,3	50-87	9,9	0,38-33,3
G	8	59,5	40-72	3,35	1,05-6,67
H	12	53,6	29-85	6,09	0,125-40,0
I	18	52,2	31-79	1,25	0,08-1,67
J	34	45,5	26-68	2,27	0,03-18,0

ANALYSIS OF RESULTS

Referring to Tables 4 and 5, as expected, the results show that increased alteration results in decreased strengths and classification values. The former must be due to both chemical and physical changes within the intact rocks. The latter is probably due to the fact that in any given geological environment it is likely that the weaker rocks will be fractured more extensively.

The results, however, exhibit both anomalous values and the usual wide dispersions. While the latter are normal, the former indicated that there were some problems associated with the original local classification system. This, it will be recalled, was based on degrees of alteration which could be recognized during the visual examination of drill core. Errors in allocating samples, or sites, to the various classification groups could bias the results significantly.

With this in mind, it was concluded that the original system should be revised. Less ambiguity might result were simplification to be achieved through combining some of the groups.

At the same time, with the original objective in mind, the results were examined to determine if the use of one of the newer methods could result in improved precision in future geotechnical analyses.

With both CSIR and NGI classification values available for all of the underground locations, the authors reviewed the data in order to obtain the corresponding values that would have resulted from the use of either Deere's or the Russian approach. The former, it should be recalled, were produced from on-site estimates. The latter were obtained by dividing the strengths of the intact rocks by 100.

Average values were then calculated for each of the ten original rock types. A summary of the ratings produced by using each of the four methods for each of the ten rock types is given in Table 6. It should be noted that there are no units for any of the values and that direct numerical comparisons are not appropriate. The most important point is the position of a rating within a scale. Thus, more meaning is given to the table if the values are converted, in descending order, to alphabetic characters. The result is shown in Table 7.

Table 6 - Average rating values resulting from the approaches considered

	Rock types in original local system									
	A	B	C	D	E	F	G	H	I	J
Methods										
Deere*	20,0	20,0	19,7	18,9	17,9	17,5	18,0	16,4	13,5	12,4
Russian	19,1	10,5	8,8	6,4	8,2	11,7	6,8	8,7	6,7	4,8
CSIR	69	81,8	63,5	65,3	59,9	67,3	59,5	53,6	52,2	45,5
NGI	150,0	232,8	66,0	65,0	15,4	9,9	3,35	6,09	1,25	2,27

*NOTE: In order to facilitate the regressions that were made the values used were NOT RQD values, but, rather, the weighted values (i.e., ratings) used in the CSIR system. The correspondence is as follows:

RQD 100-90%;	CSIR rating 20
90-75%	17
75-50%	13
50-25%	8
<25%	3

Table 7 - Alphabetic classings of values given in Table 6

	Rock types in original local system									
	A	B	C	D	E	F	G	H	I	J
Methods										
Deere	A	B	C	D	F	G	E	H	I	J
Russian	A	C	D	I	F	B	G	E	H	J
CSIR	B*	A*	E	D	F	C	G	H	I	J
NGI	B*	A*	C	D	E	F	H	G	J	I

*NOTE: These positions have been determined by a single site assessment in rock type A.

On inspection of the table it is evident that the strongest and the weakest rocks (with regards to possible support requirements) are identified, with varying degrees of precision, through all of the methods. The greatest correspondence with the original order, however, is obtained through the use of either Deere's or the NGI approaches. The next closest agreement results from the CSIR approach.

As a part of the analysis, regressions were performed on the data produced through the various methods when considered as pairs (i.e.: CSIR vs NGI, etc.). Since none of the correlation coefficients exceeded 0,87, the results are not given herein.

The result of one analysis which leads to what we believe is an important conclusion, however, is shown in Fig. 1. In comparing the verbal descriptions of rock mass qualities that are associated with values in both the CSIR and NGI systems, it was observed that the use of the NGI system results in fewer chances of forming a wrong impression of rock mass quality. In our opinion, if a rock may be described as being "Good" through one method, it should also be described as being "Good" through another.

That there is not always good agreement between the methods is illustrated by Fig. 1. It will be observed that there were 23 instances in which rock would have been described as being of "Good", or better, quality by the CSIR method, and described as of lesser quality on the NGI scale. When viewed from the opposite perspective, however, there were only 7 instances when this difficulty would have arisen. Because of this, it is believed that ratings which are obtained by following the NGI method are probably more conservative

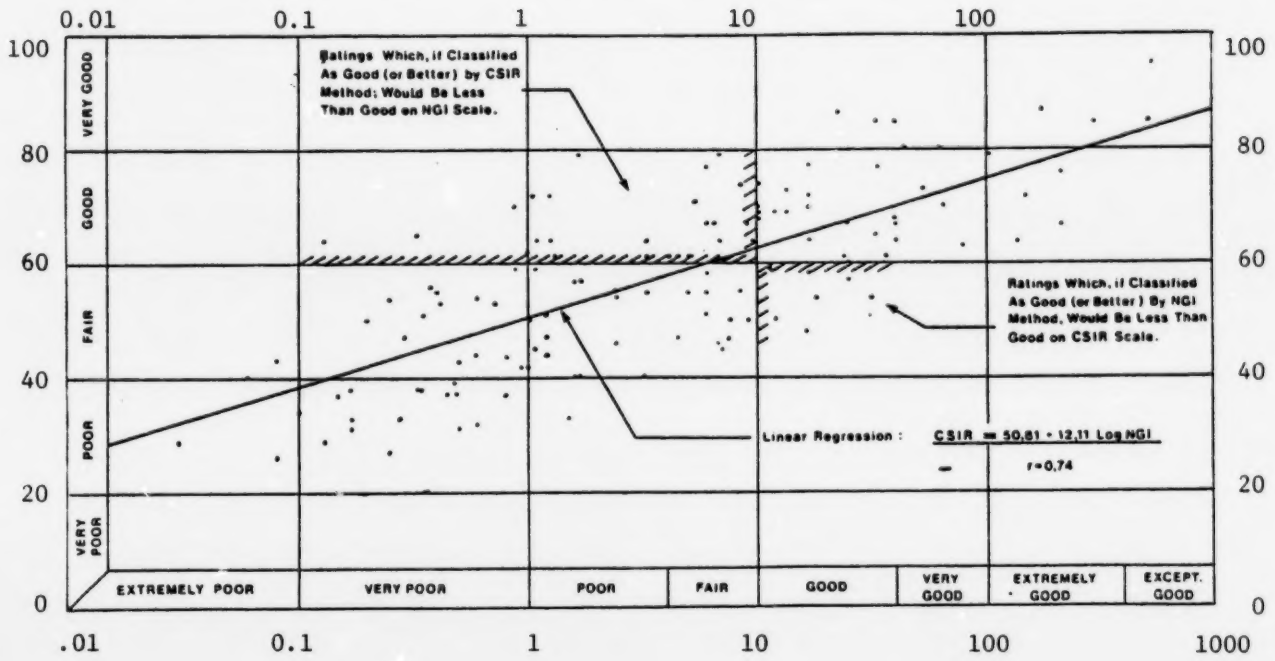

Fig. 1 - NGI classification (horizontal axis) CSIR classification (vertical axis).

as regards to verbal descriptions of quality. From a safety point of view this is desirable. Economically, however, the reverse is true.

CONCLUSIONS

Of the four methods that were considered, the authors believe that that proposed by the NGI was the most appropriate for the situation. At the mine site, the rock mass is highly altered and extensively fractured. Because of this, any system which is not weighted heavily towards the importance of structural features is not acceptable. Additionally, an element of conservatism is also desirable - especially at the initial stages of using methods of analysis which are new to a site. With experience, and greater confidence, conservatism may be reduced. The opposite approach involves much greater risks.

The CSIR method, then, was also considered to be an excellent technique. For reasons that have been mentioned, however, it was of secondary preference and it was not chosen for further use locally.

Both the NGI and CSIR approaches were found to be easy to use under field conditions. Either can be recommended without hesitation. The advantage of the former, however, is that a total evaluation can be made at the working face. The advantage of the latter is that ratings are obtained with greater simplicity. The disadvantages of both systems are considered to be of only minor importance. In the case of the CSIR method, these are related to a certain reliance on test values. As regards the NGI Method, these relate to its rather complicated appearance.

Interestingly, the weaker and stronger rocks were consistently identified through <u>all</u> of the approaches - thus confirming that the original local classification system, based on visible alteration, was reasonably accurate for purposes of estimating the anticipated strength of the local rock mass. This, in itself, is an incentive for the development of "In-House" approaches. The necessity of weighting such approaches towards the importance of structural features has, it is hoped, been shown clearly.

REFERENCES

1. Protodyakanov, M.M. Quoted in personal communication from H. Wang; 1907.

2. Terzaghi, K. "Rock defects and loads on tunnel supports"; In: Rock Tunnelling with Steel Supports; Commercial Shearing and Stamping Co.; ed. by R.V. Proctor and T. White; Youngstown, Ohio; 1946.

3. Coates, D.F. "Classification of rock for rock mechanics"; Int. Jour. of Rock Mech. & Min. Sci., Vol. 1; 1964.

4. Deere, D.U. and Miller, R.P. "Engineering classification and index properties for intact rock"; Tech. Rep. No. AFNL-TR-65-116; Air Force Weapons Lab.; New Mexico, USA; 1966.

5. Bieniawski, Z.T. "Rock mass classification in rock engineering"; Proc. Sym. on Expl. for Rock Eng.; Vol. 1; Johannesburg; 1976.

6. Barton, N., Lien, R. and Lunde, J. "Engineering classification of rock masses for the design of tunnel support"; Rock Mech. 6-4; 1974.

7. Hoek, E. and Brown, E.T. "Underground excavations in rock"; Inst. Min. and Met.; London; 1980.

POOR

QUALITY

ORIGINAL